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Mohammadi

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(54) **METHOD OF MANUFACTURING A DAMPER TUBE**

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F16F 9/32 (2006.01)
F16F 9/54 (2006.01)

(52) **U.S. Cl.**
CPC ***F16F 9/3242*** (2013.01); ***F16F 9/3271*** (2013.01); ***F16F 9/54*** (2013.01)

(58) **Field of Classification Search**
CPC F16F 9/3242; F16F 9/3271; F16F 9/54
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,942,232 A *	3/1976	McGuire	G21C 3/041 29/890.14
3,972,353 A *	8/1976	McGuire	G21C 3/041 138/42
9,562,630 B2 *	2/2017	Daton-Lovett	F16L 9/02
2013/0161141 A1 *	6/2013	Maegawa	F16F 9/3221 188/297

FOREIGN PATENT DOCUMENTS

DE	833001	3/1952
DE	10004124	5/2001

* cited by examiner

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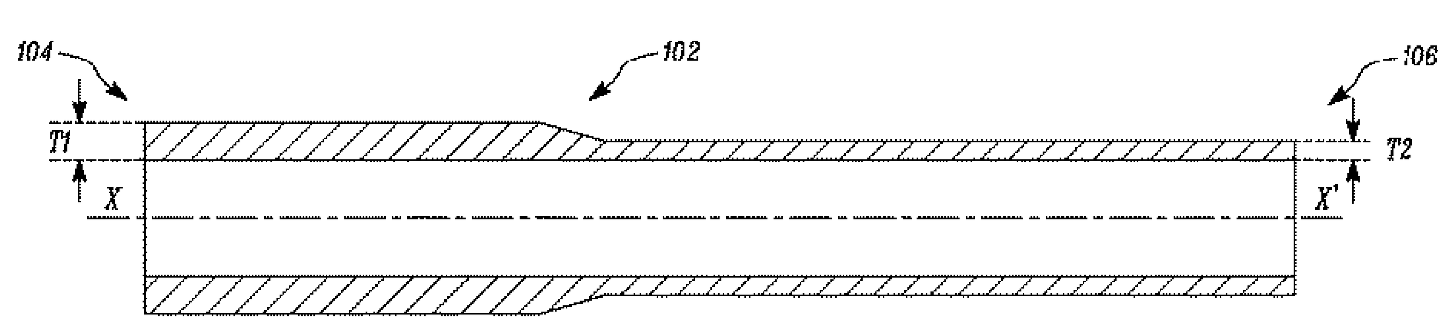
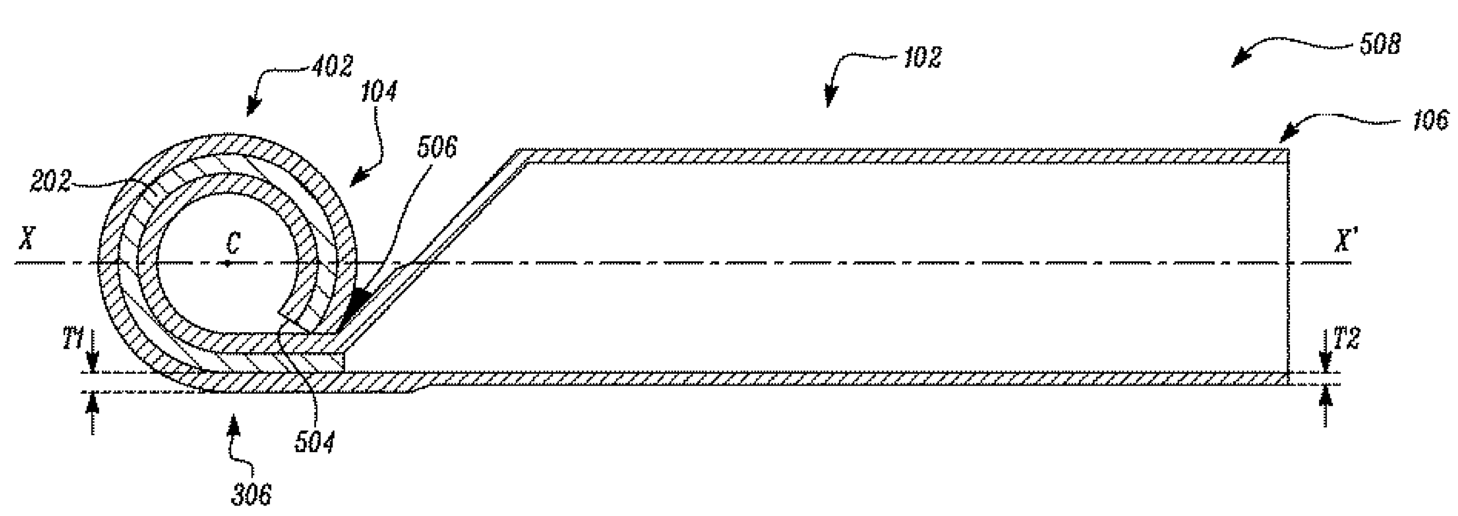
(57) **ABSTRACT**

A method of manufacturing a damper tube is provided. The method includes providing a tube having a first end and a second end opposite to the first end. The method includes providing a reinforcing insert, at least partly, within the first end of the tube. The method includes flattening a portion of the first end of the tube. The method also includes bending at least one of the reinforcing insert and the flattened portion of the first end of the tube into a loop. The method further includes connecting an edge of the loop to the tube.

9 Claims, 11 Drawing Sheets





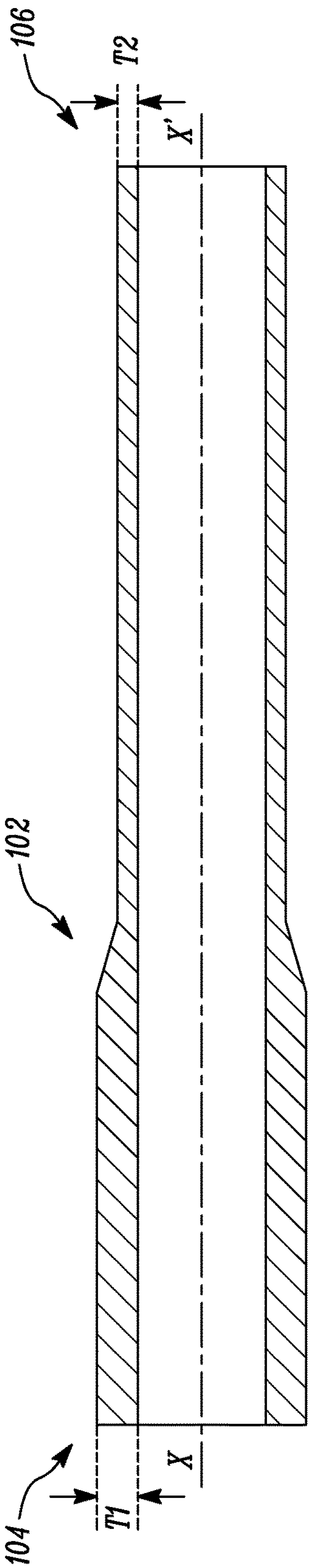


FIG. 1A

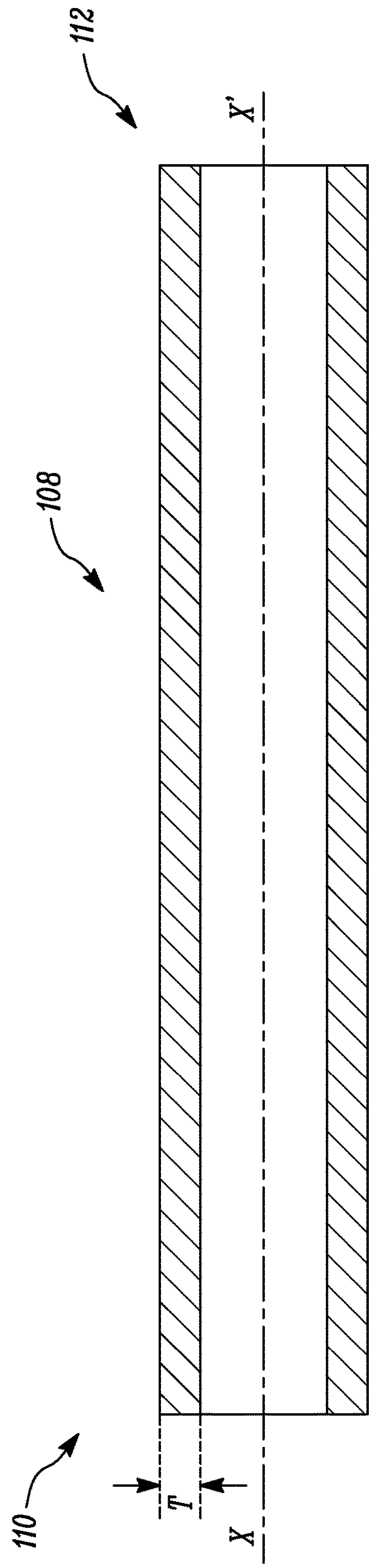


FIG. 1B

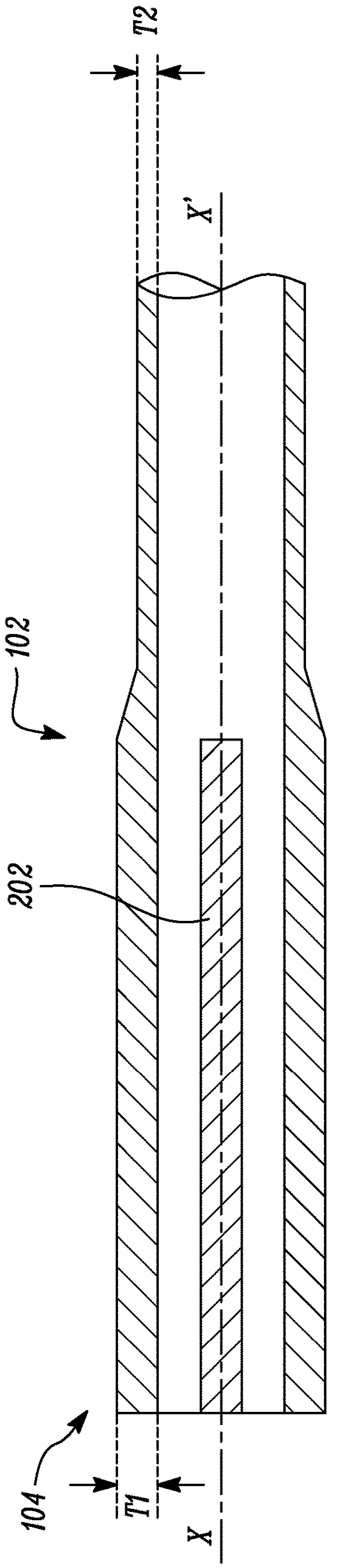


FIG. 2A

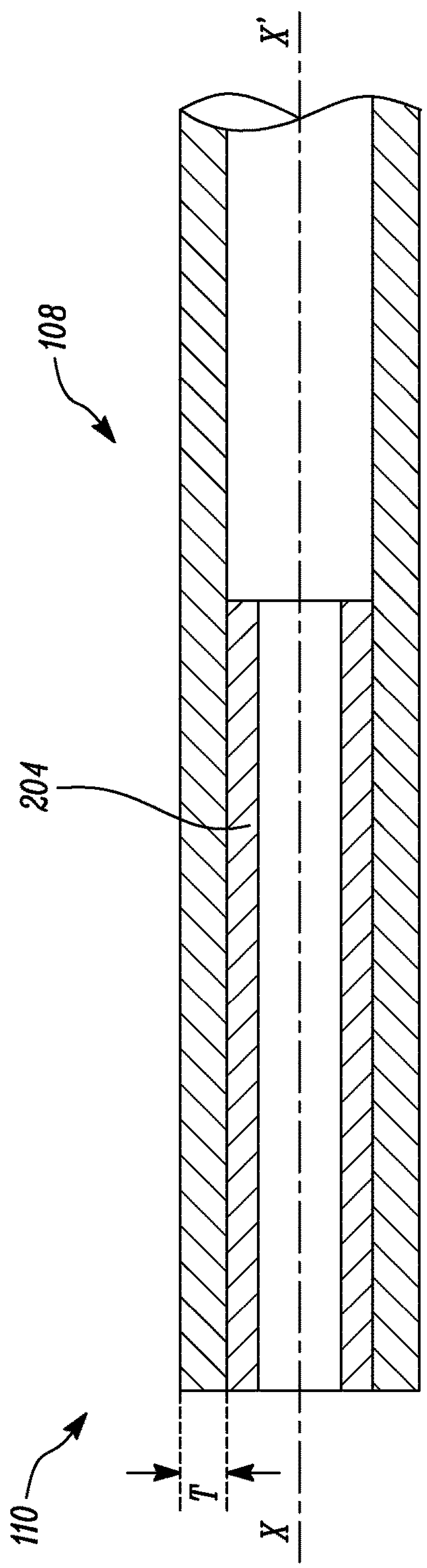


FIG. 2B

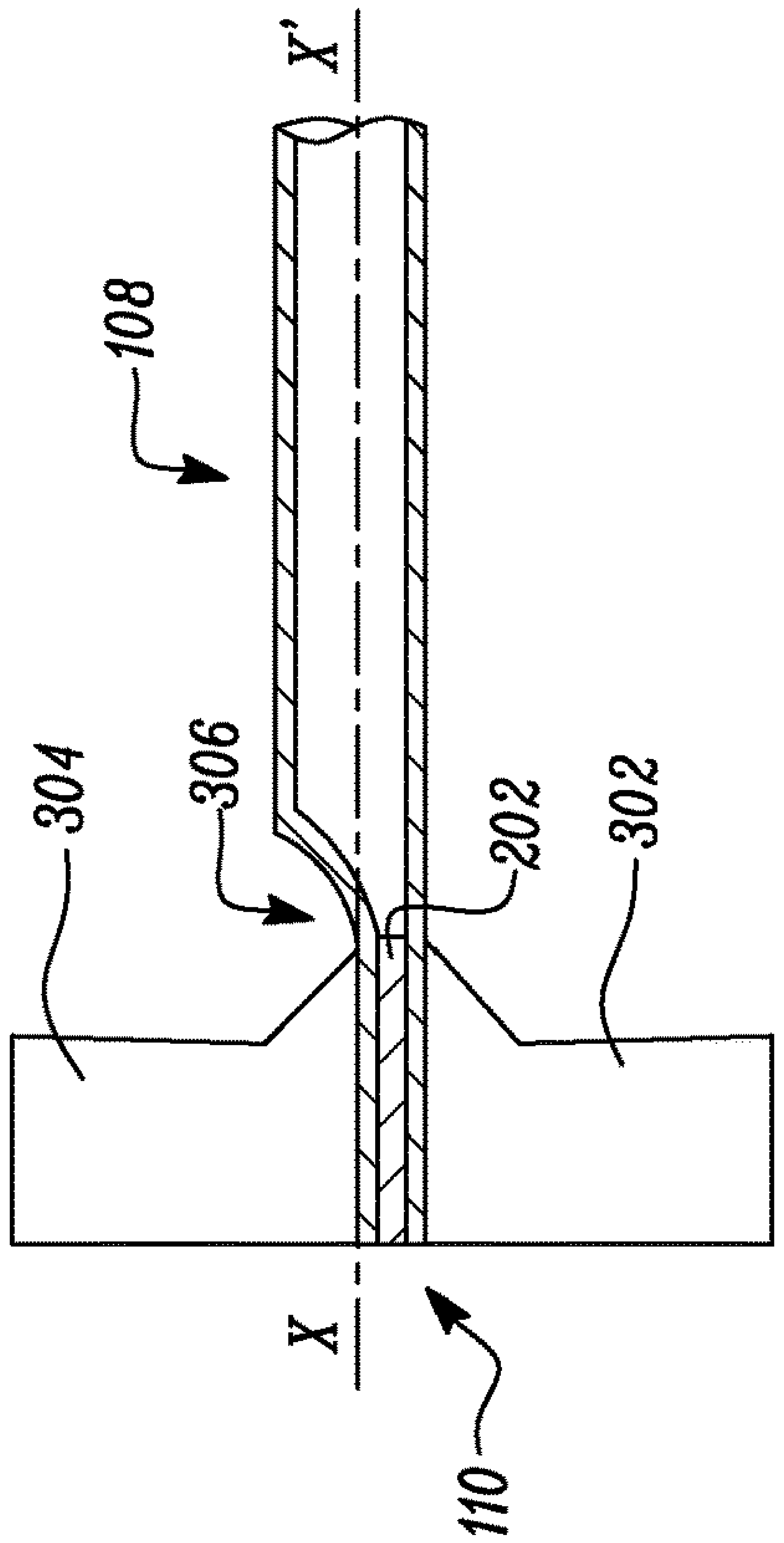


FIG. 3B

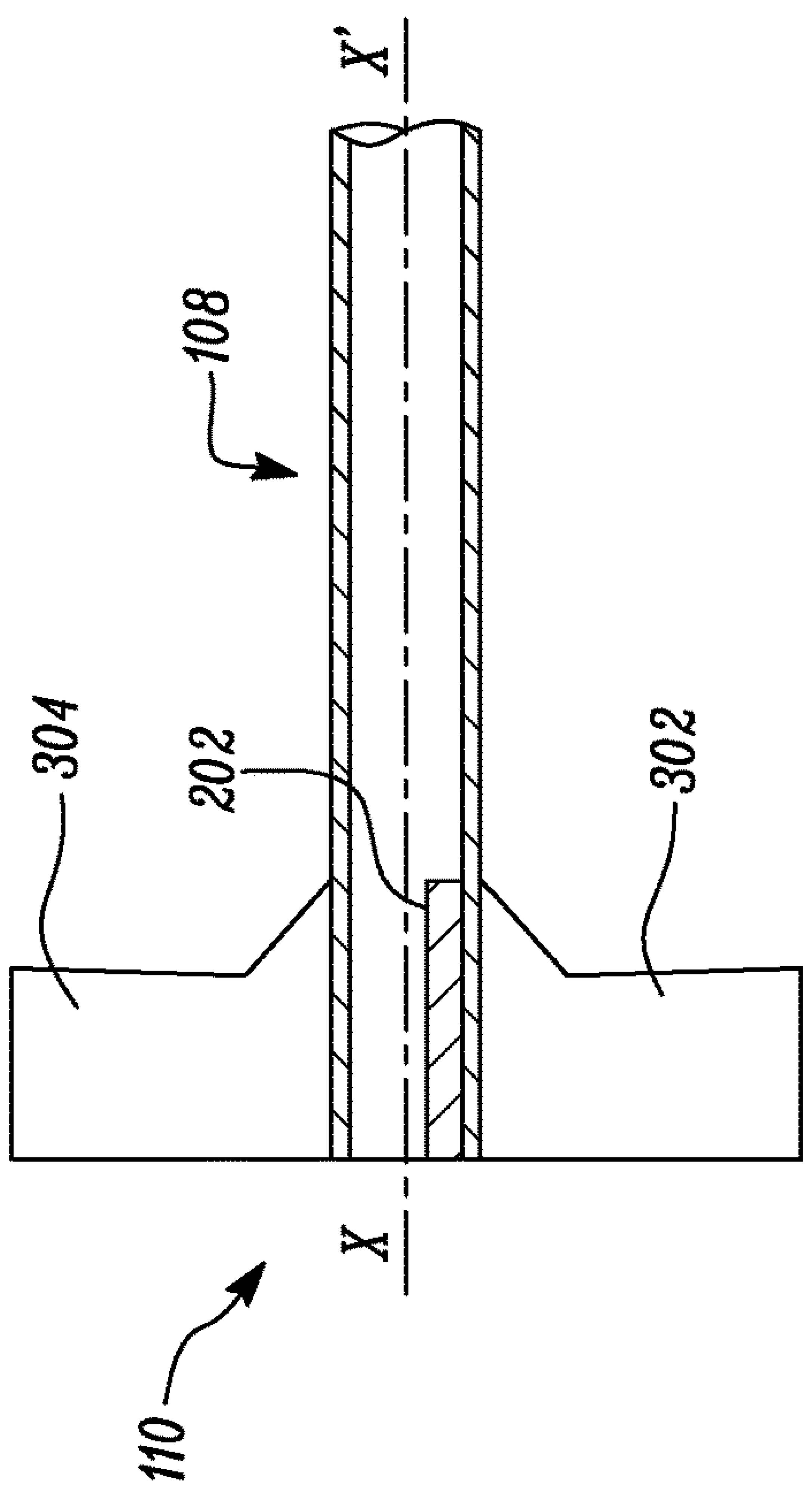


FIG. 3A

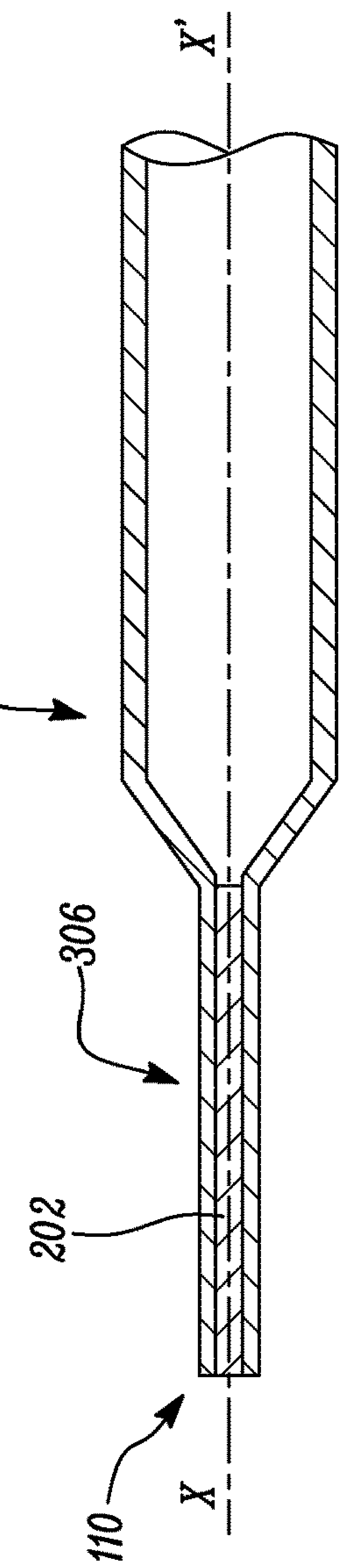


FIG. 3C

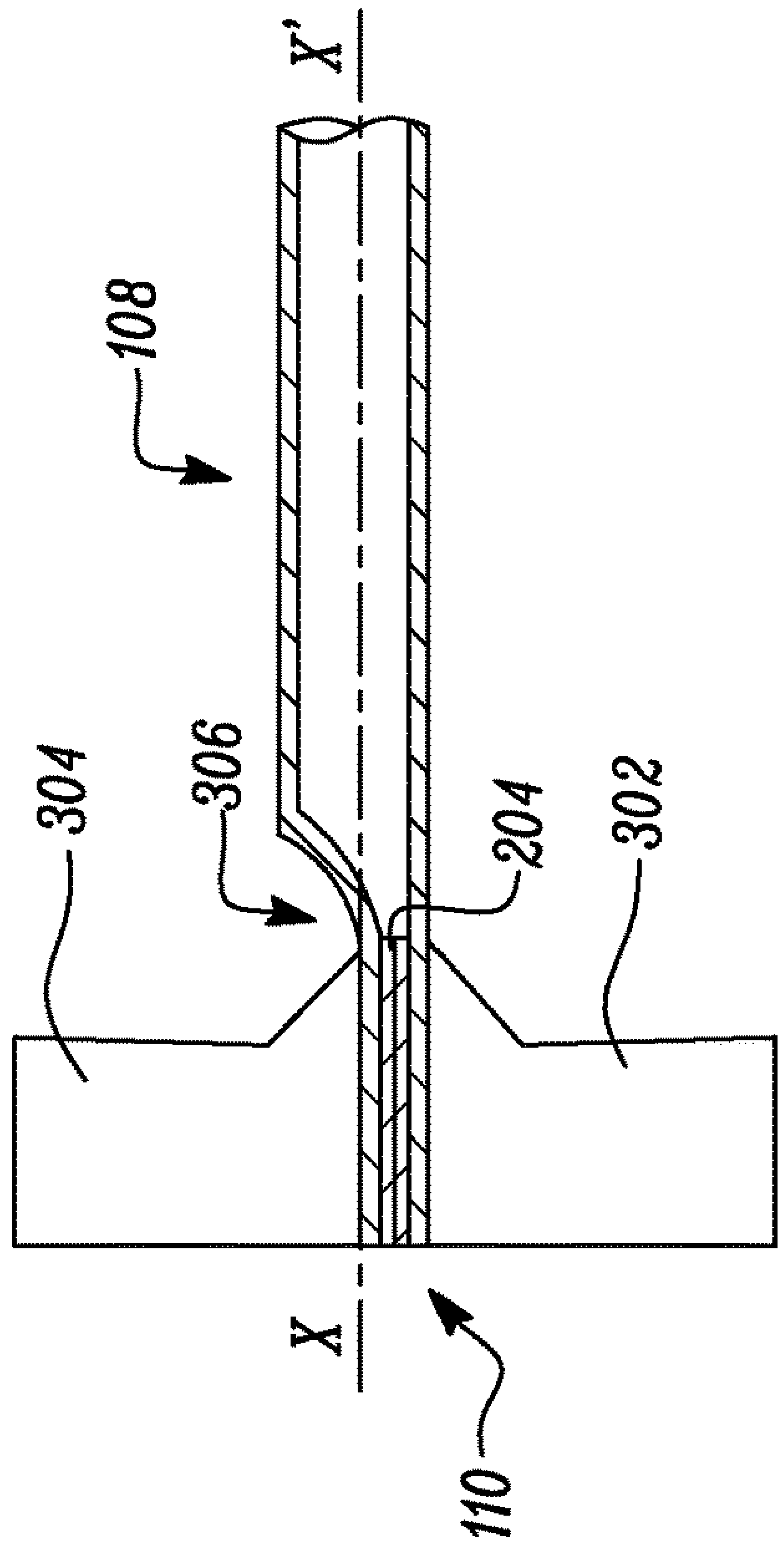


FIG. 3E

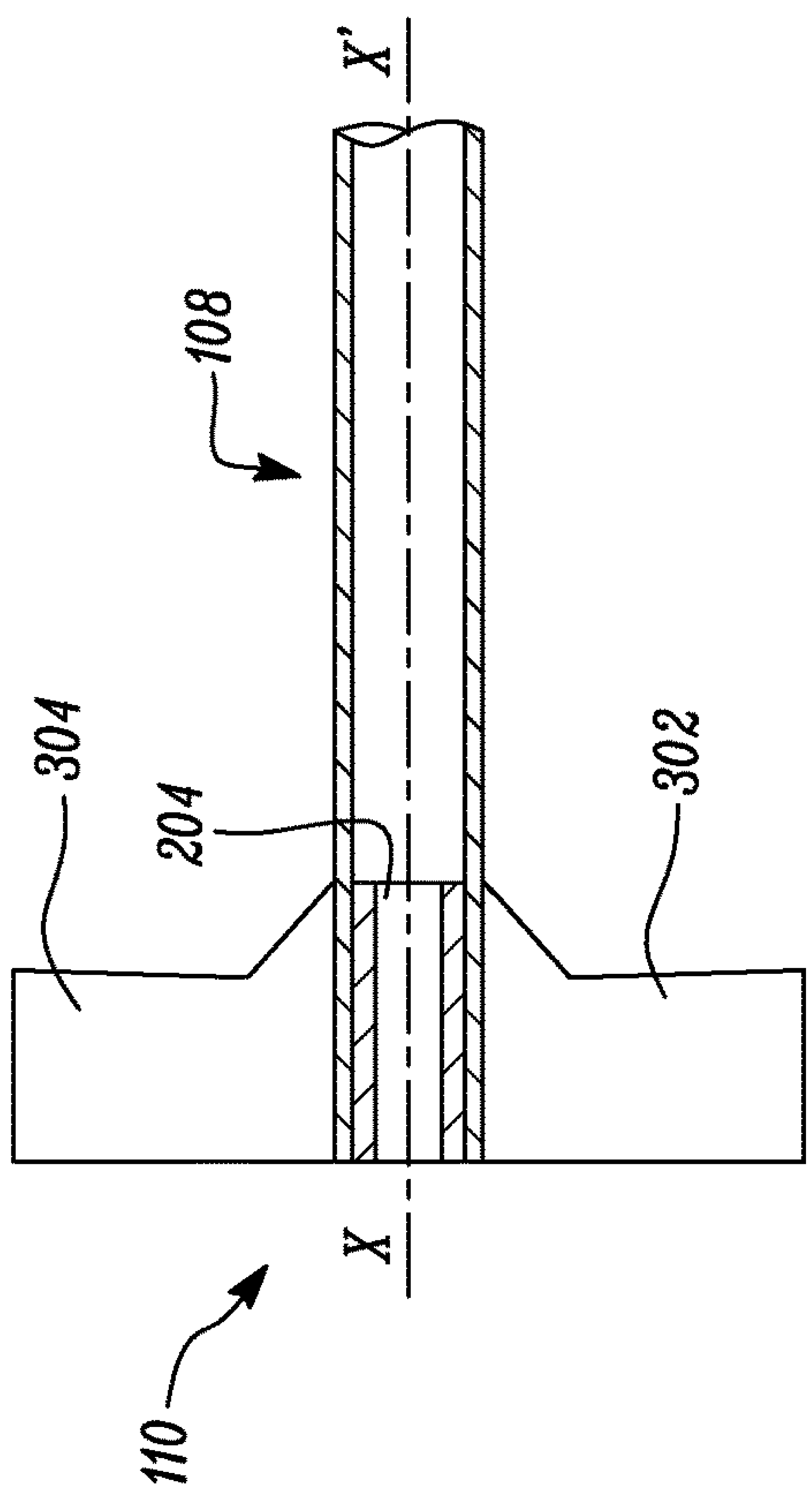


FIG. 3D

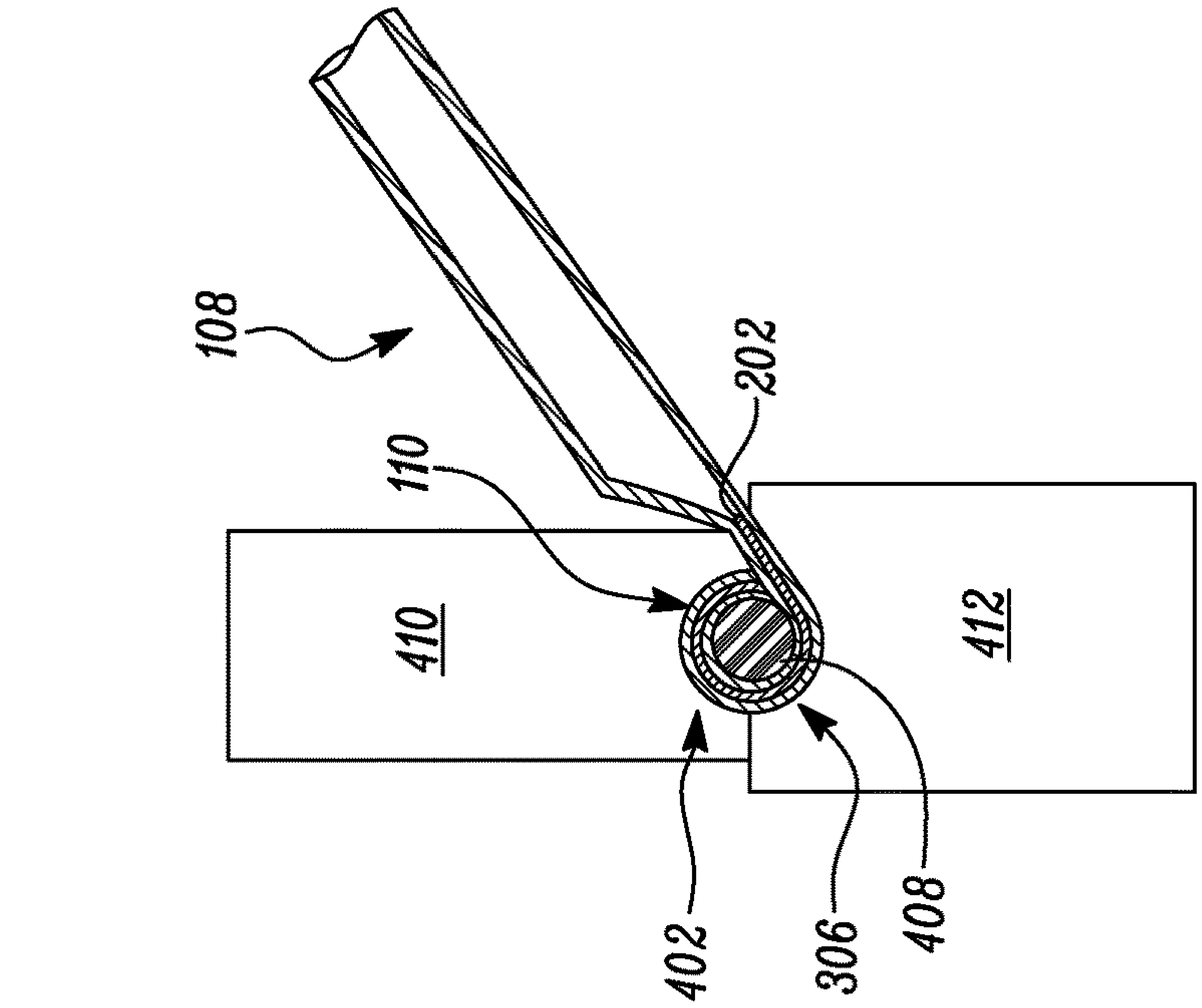


FIG. 4C

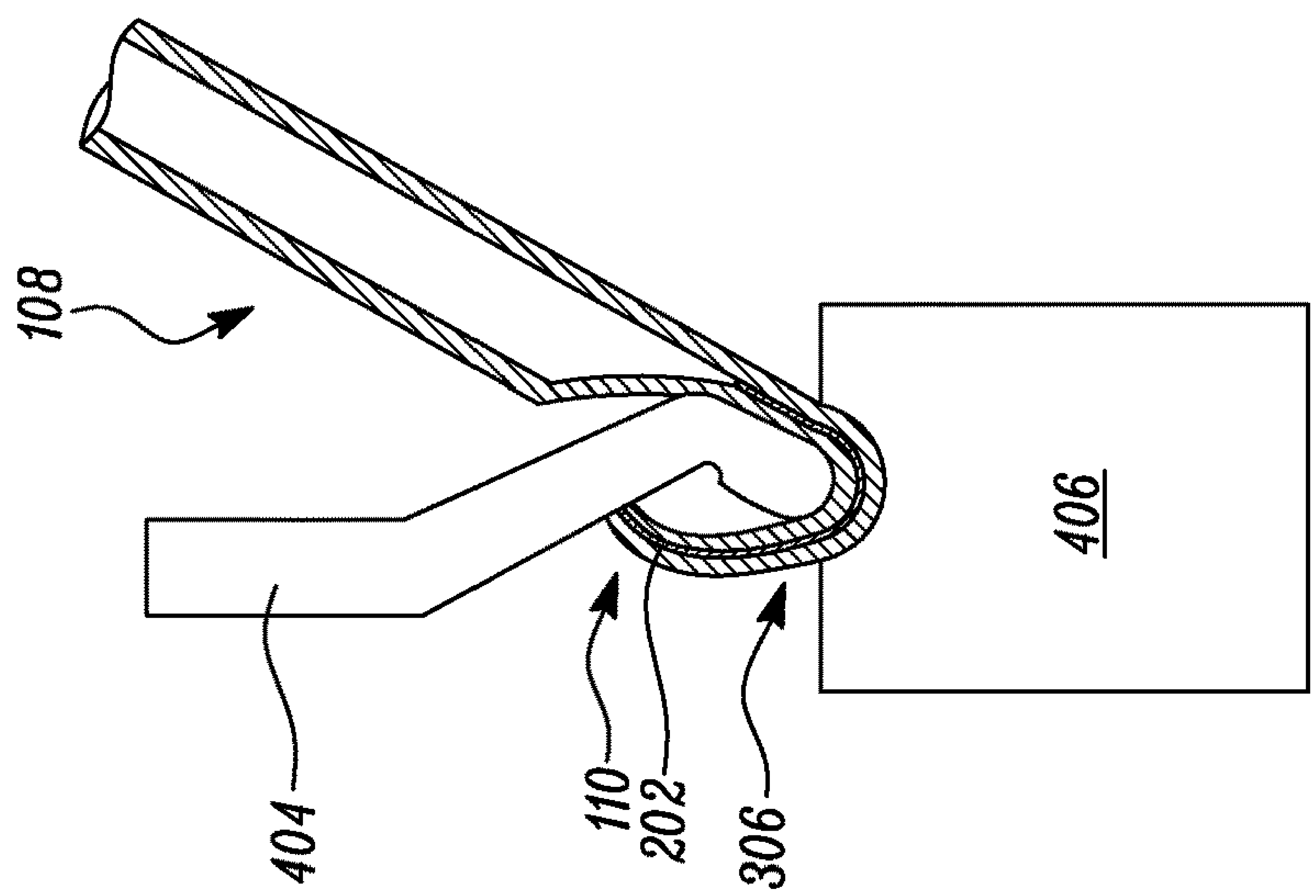


FIG. 4B

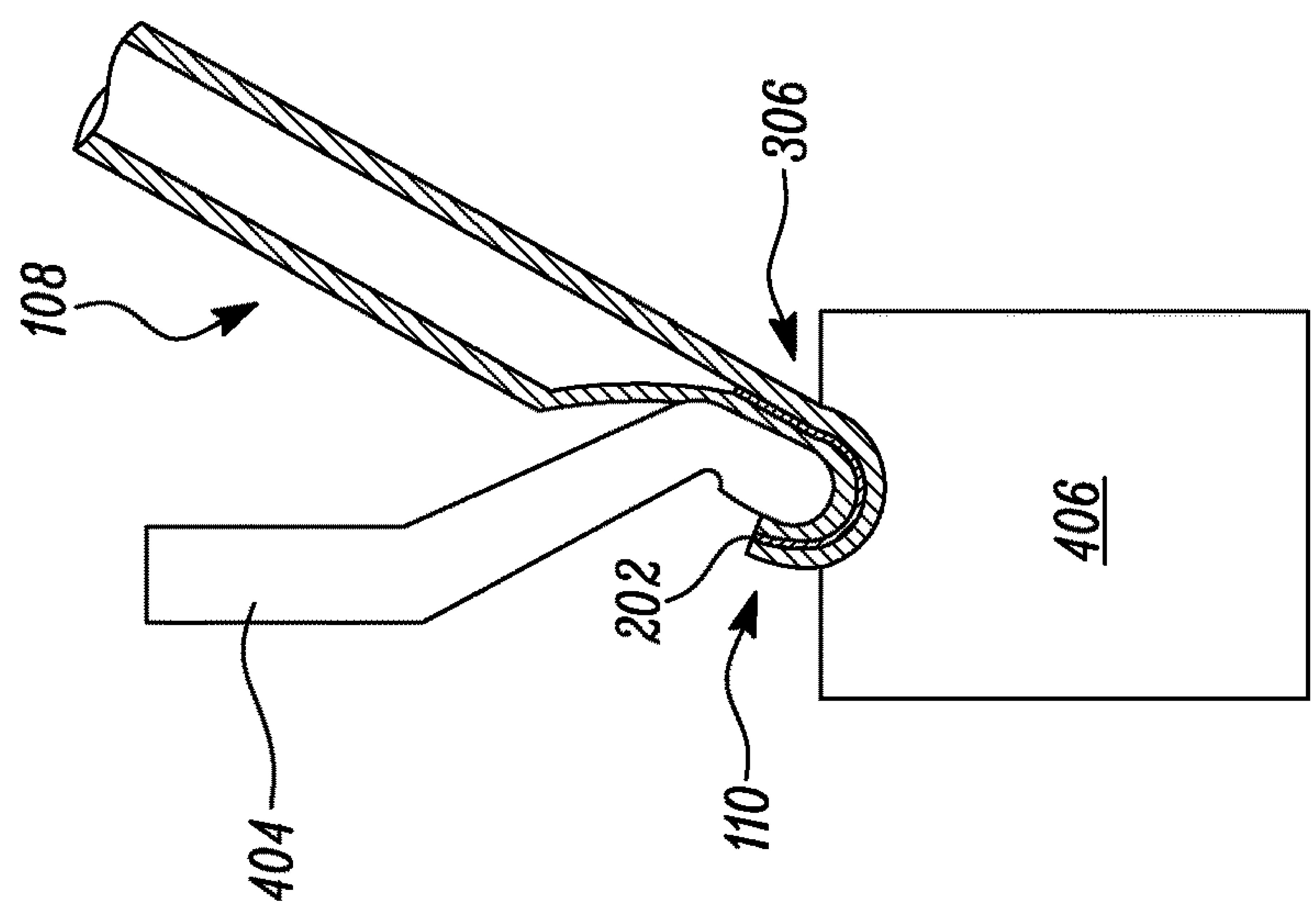


FIG. 4A

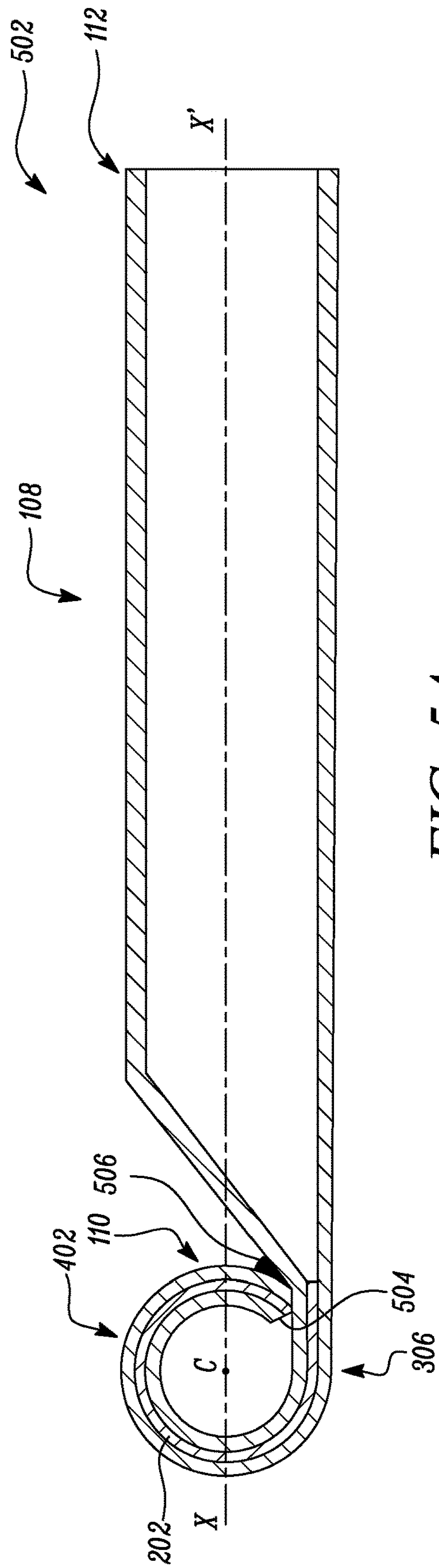

502
112
X'
108
506
110
402
504
306
C
202
X

FIG. 5A

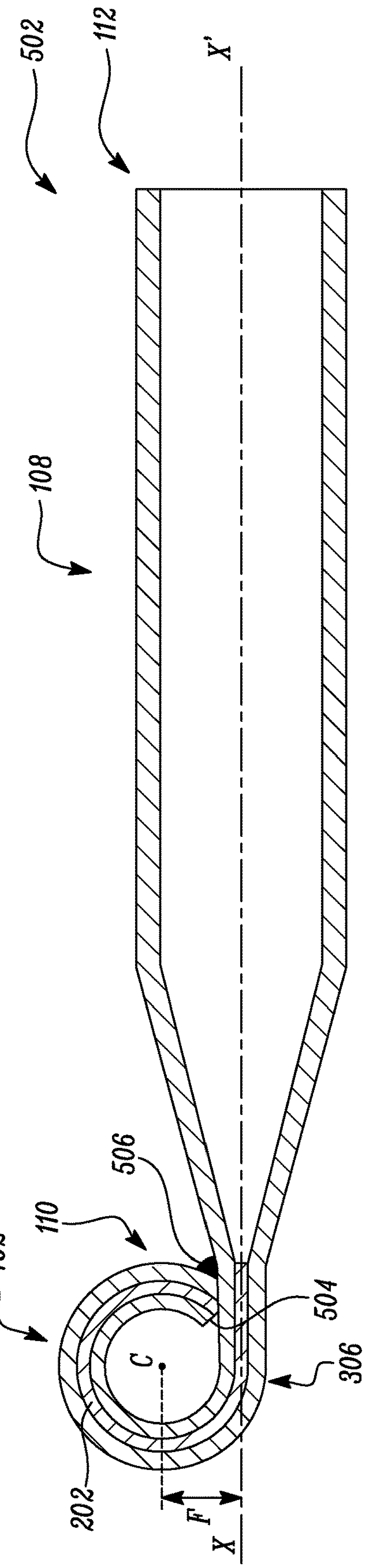

502
112
X'
108
506
110
402
504
306
C
202
F
X

FIG. 5B

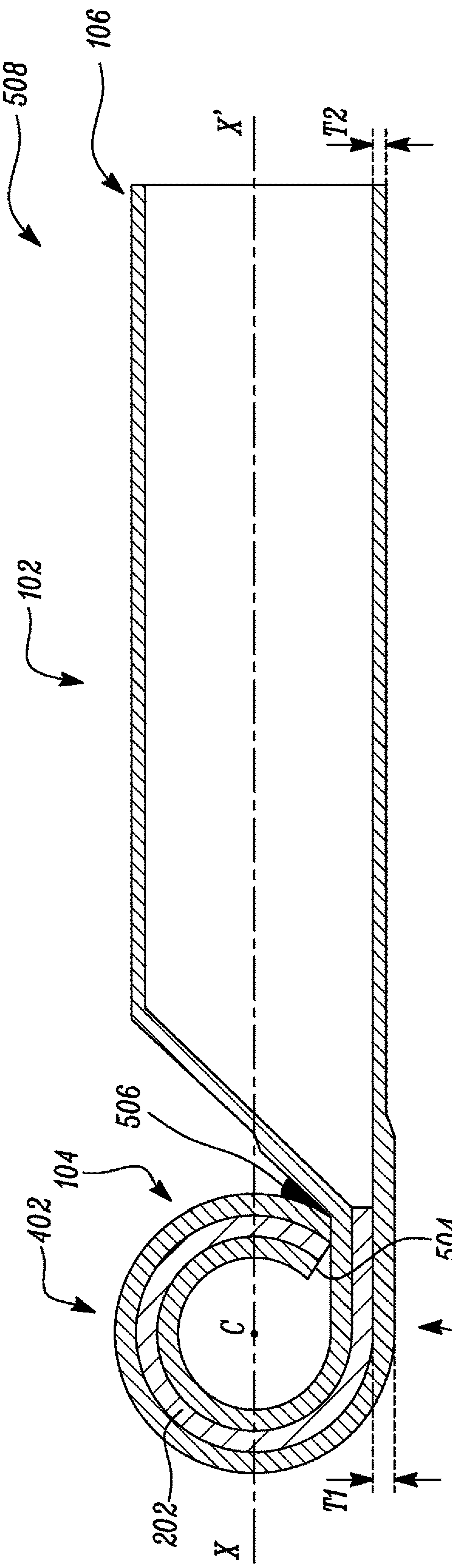

508
106
X'
T2
102
506
104
402
504
C
306
202
T1
X

FIG. 5C

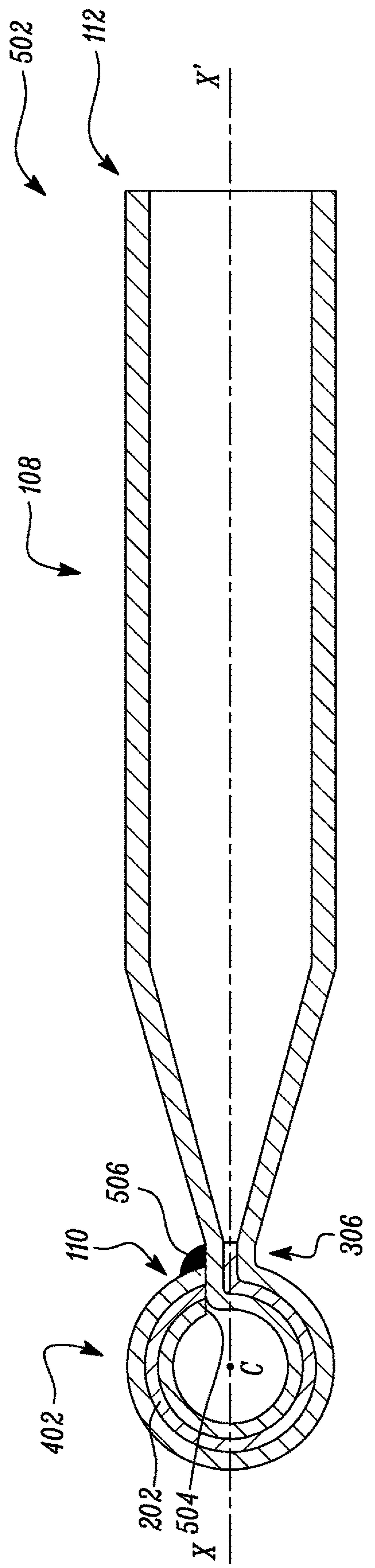

502
112
X'
108
506
110
306
402
C
202
504
X

FIG. 5D

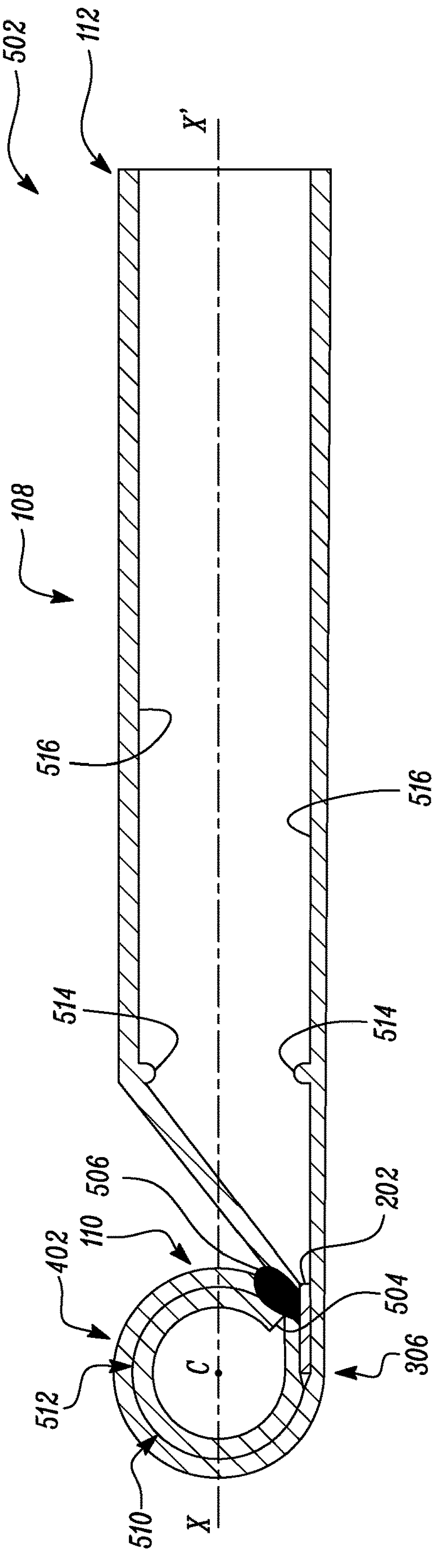


FIG. 5E

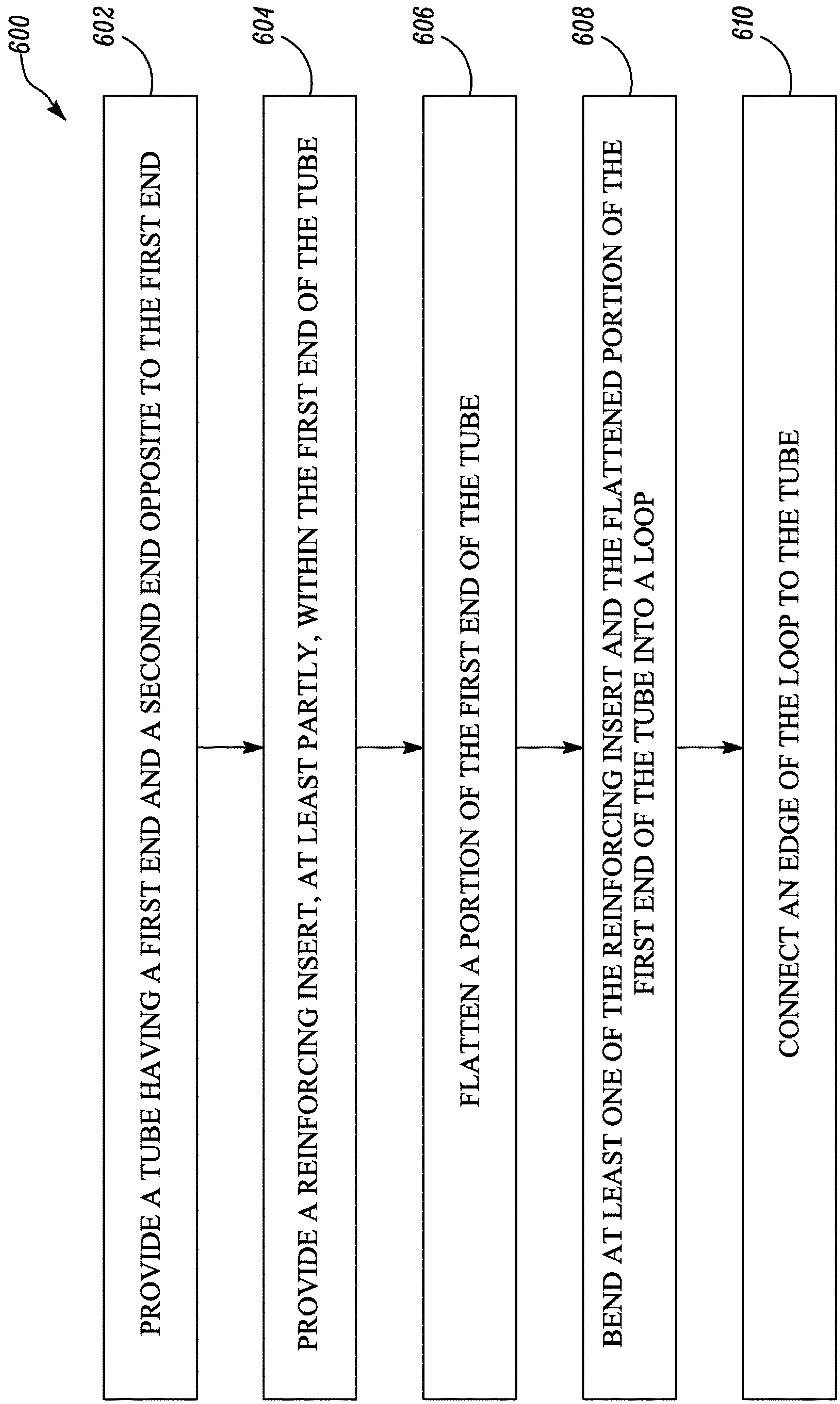

600
602
PROVIDE A TUBE HAVING A FIRST END AND A SECOND END OPPOSITE TO THE FIRST END
604
PROVIDE A REINFORCING INSERT, AT LEAST PARTLY, WITHIN THE FIRST END OF THE TUBE
606
FLATTEN A PORTION OF THE FIRST END OF THE TUBE
608
BEND AT LEAST ONE OF THE REINFORCING INSERT AND THE FLATTENED PORTION OF THE FIRST END OF THE TUBE INTO A LOOP
610
CONNECT AN EDGE OF THE LOOP TO THE TUBE

FIG. 6

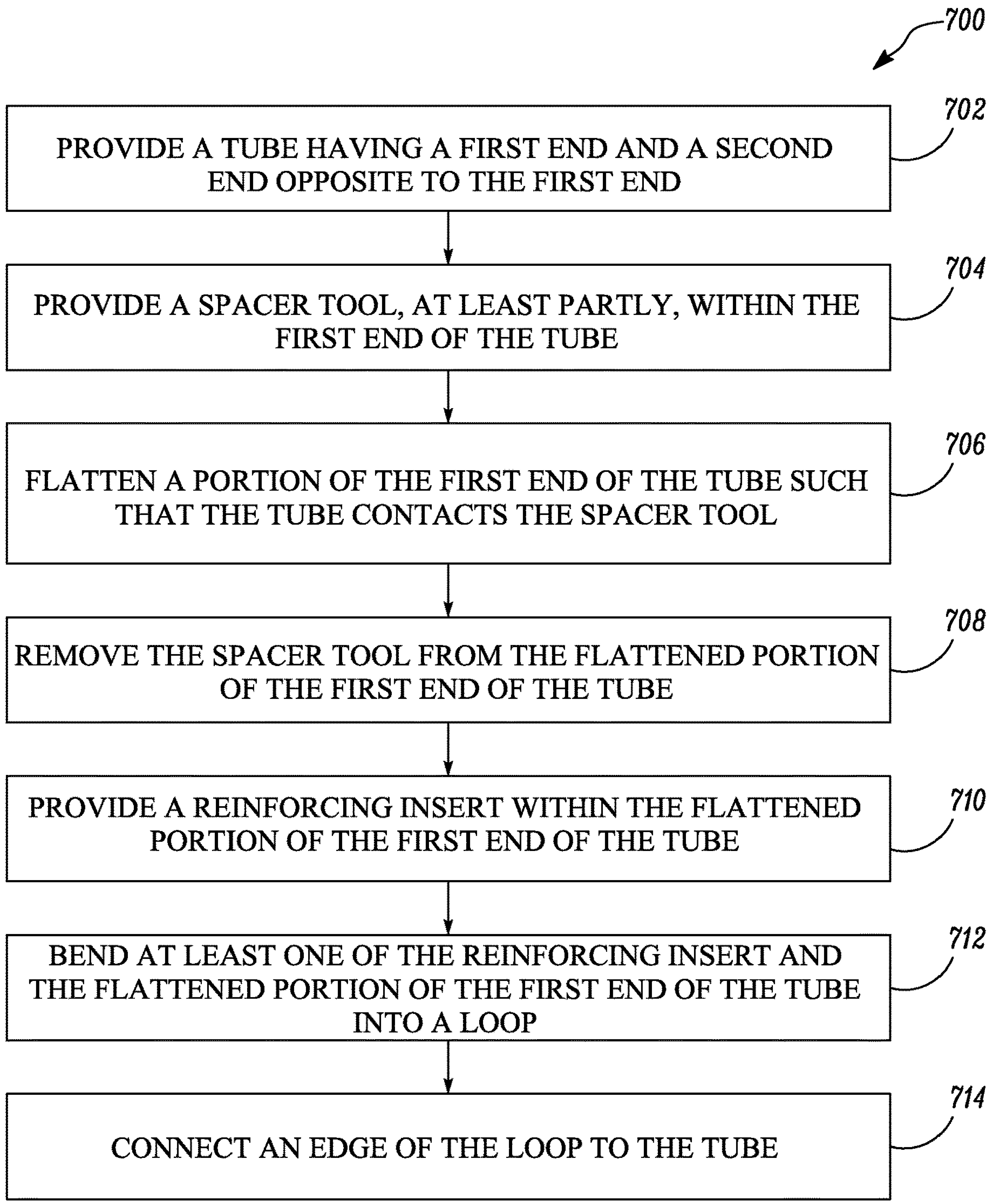

700
702
PROVIDE A TUBE HAVING A FIRST END AND A SECOND END OPPOSITE TO THE FIRST END
704
PROVIDE A SPACER TOOL, AT LEAST PARTLY, WITHIN THE FIRST END OF THE TUBE
706
FLATTEN A PORTION OF THE FIRST END OF THE TUBE SUCH THAT THE TUBE CONTACTS THE SPACER TOOL
708
REMOVE THE SPACER TOOL FROM THE FLATTENED PORTION OF THE FIRST END OF THE TUBE
710
PROVIDE A REINFORCING INSERT WITHIN THE FLATTENED PORTION OF THE FIRST END OF THE TUBE
712
BEND AT LEAST ONE OF THE REINFORCING INSERT AND THE FLATTENED PORTION OF THE FIRST END OF THE TUBE INTO A LOOP
714
CONNECT AN EDGE OF THE LOOP TO THE TUBE

FIG. 7

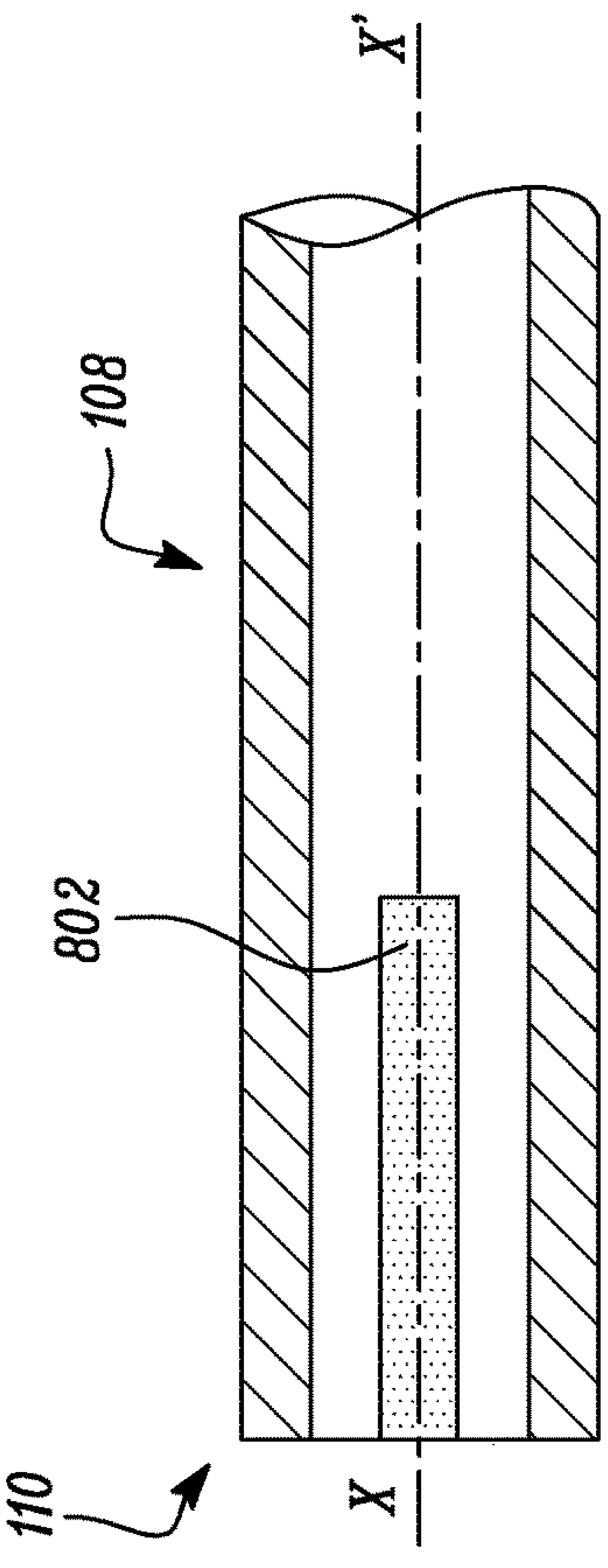


FIG. 8A

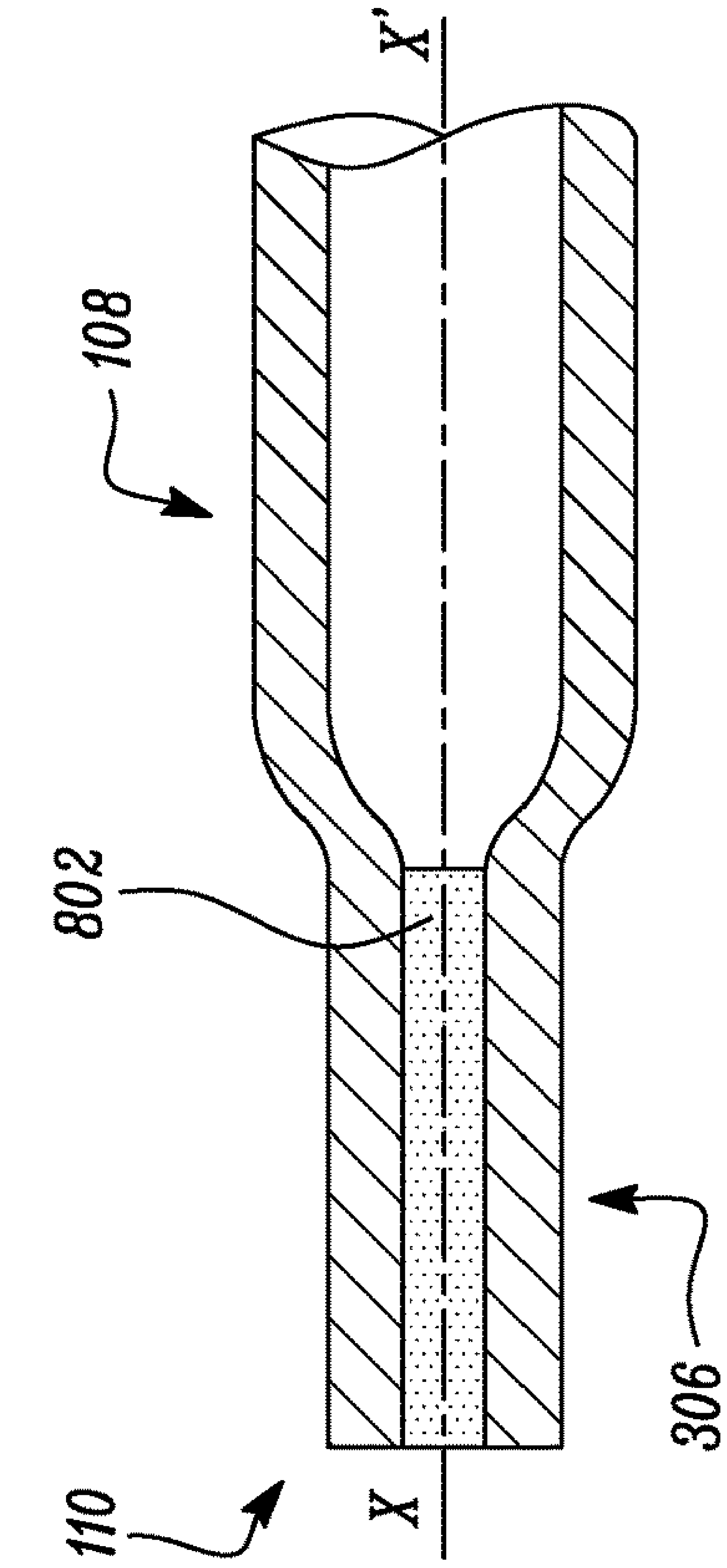


FIG. 8B

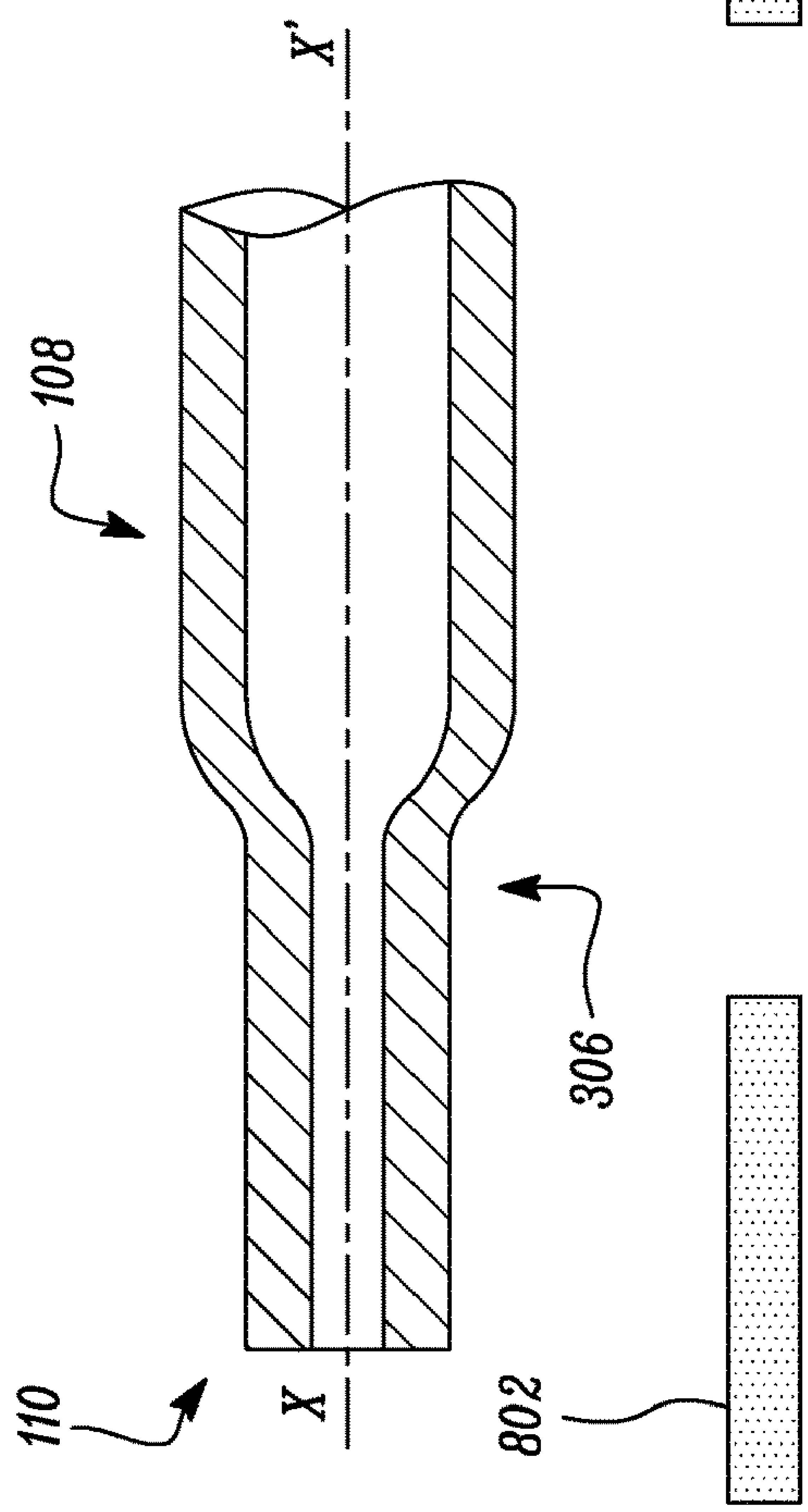


FIG. 8C

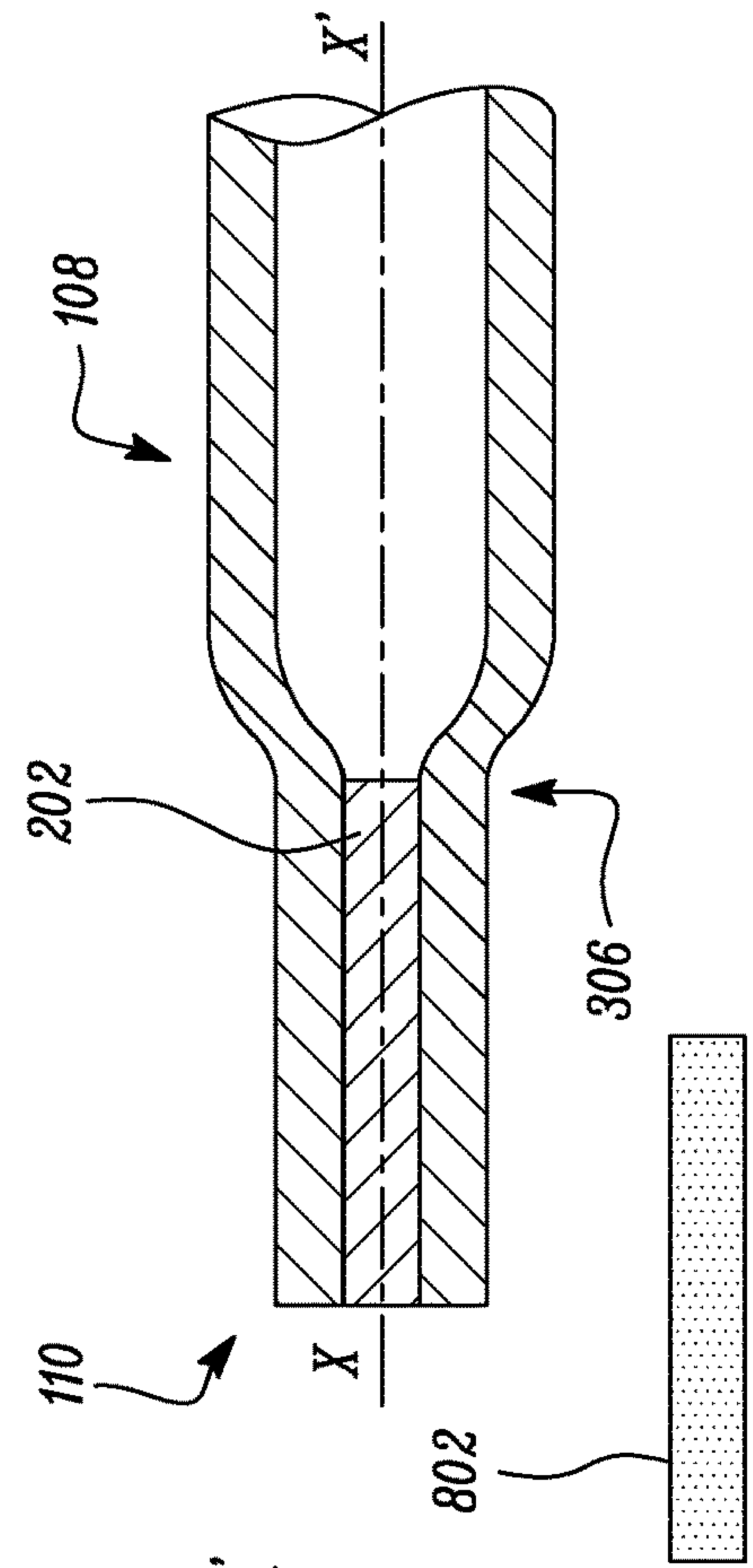


FIG. 8D

METHOD OF MANUFACTURING A DAMPER TUBE

TECHNICAL FIELD

The present disclosure relates to a method of manufacturing a damper tube. More particularly, the present disclosure relates to a method for manufacturing the damper tube for a suspension system.

BACKGROUND

A damper tube is generally used as a base assembly for a suspension system, such as a shock absorber. The damper tube may be manufactured using one or more components, joints, and/or manufacturing processes. As such, the manufacturing of the damper tube may be complex, time intensive, labor intensive, and expensive. Also, a material of construction used for the damper assembly may add considerable weight to the damper tube. Further, a change in a design of the damper tube may demand a change in the manufacturing process. To achieve this, alternative manufacturing process may have to be employed based on the new design.

In some situations, automated manufacturing processes may be employed which may relieve the operator and increase throughput, thus, improving production rate and production costs. Moreover, a material of construction and specific techniques used to process the material may significantly govern the production costs. Therefore, both the material and the processes involved may need to be considered for reducing the complexity and costs. Conventional methods of manufacturing the damper tube may include multiple components and/or manufacturing steps increasing complexity of the manufacturing process, increasing investment cost, reducing logistic flow, and making the damper tube heavy and expensive. Hence, there is a need for an improved method of manufacturing the damper tube to reduce complexity, weight, and costs.

Given description covers one or more above mentioned problems and discloses a method and a system to solve the problems.

SUMMARY

In an aspect of the present disclosure, a method of manufacturing a damper tube is provided. The method includes providing a tube having a first end and a second end opposite to the first end. The method includes providing a reinforcing insert, at least partly, within the first end of the tube. The method includes flattening a portion of the first end of the tube. The method also includes bending at least one of the reinforcing insert and the flattened portion of the first end of the tube into a loop. The method further includes connecting an edge of the loop to the tube.

In another aspect of the present disclosure, another method of manufacturing the damper tube is illustrated. The method includes providing a tube having a first end and a second end opposite to the first end. The method includes providing a spacer tool, at least partly, within the first end of the tube. The method includes flattening a portion of the first end of the tube such that the tube contacts the spacer tool. The method includes removing the spacer tool from the flattened portion of the first end of the tube. The method includes providing a reinforcing insert within the flattened portion of the first end of the tube. The method also includes bending at least one of the reinforcing insert and the flattened portion of the first end of the tube into a loop. The method further includes connecting an edge of the loop to the tube.

Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1**A and **1**B illustrate cross sectional views of exemplary tubes, according to an aspect of the present disclosure;

FIGS. **2**A and **2**B illustrate cross sectional views of exemplary reinforcing inserts disposed within the exemplary tubes, according to an aspect of the present disclosure;

FIGS. **3**A, **3**B, **3**C, **3**D, and **3**E illustrate different steps of flattening the exemplary tube, according to an aspect of the present disclosure;

FIGS. **4**A, **4**B, and **4**C illustrate different steps of bending the exemplary reinforcing insert and the exemplary tube, according to an aspect of the present disclosure;

FIGS. **5**A, **5**B, **5**C, **5**D and **5**E illustrate cross sectional views of exemplary damper tubes, according to an aspect of the present disclosure;

FIG. **6** illustrates a flowchart of a method of manufacturing the damper tube, according to an aspect of the present disclosure;

FIG. **7** illustrates a flowchart of another method of manufacturing the damper tube, according to another aspect of the present disclosure; and

FIGS. **8**A, **8**B, **8**C and **8**D illustrate different steps of flattening the exemplary tube, according to another aspect of the present disclosure.

DETAILED DESCRIPTION

Wherever possible, the same reference numbers will be used throughout the drawings to refer to same or like parts. The present disclosure relates to a method of manufacturing a damper tube **502**, **508** (shown in FIGS. **5**A, **5**B, **5**C, **5**D and **5**E). The damper tube **502**, **508** may be a portion of a base or strut assembly (not shown) of a shock absorber (not shown) used in a suspension system (not shown). The suspension system may be employed for shock dampening in various applications, such as automotive, aviation, aerospace, heavy machinery, marine, transportation, industrial, and the like. The damper tube **502**, **508** may be adapted to enclose one or more components of the shock absorber, such as a piston, a volume of a working fluid, seals, and the like.

Referring to FIG. **1**A, a cross sectional view of an exemplary tube **102** is illustrated. The tube **102** has a substantially hollow and elongated configuration defining a central axis X-X'. The tube **102** includes a first end **104** and a second end **106**. The second end **106** is opposite the first end **104**. Also, in the illustrated embodiment, the tube **102** has a varying thickness along a length thereof. More specifically, the tube **102** has a first thickness "T**1**" at the first end **104** and a second thickness "T**2**" at the second end **106**.

In the illustrated embodiment, the first thickness "T**1**" is greater than the second thickness "T**2**". In other embodiments, the tube **102** may include multiple thicknesses along the length thereof. In other embodiments, as shown in FIG. **1**B, the tube **108** may have a constant thickness "T" along the length between the first end **110** and the second end **112** thereof. The tube **102**, **108** may be made of a material, such as a metal, an alloy, and the like. The method of manufacturing the damper tube **502** will be now explained with reference to the tube **108** having constant thickness "T" for the purpose of clarity and explanation. It should be noted that, in other embodiments, the damper tube **508** may be manufactured using the tube **102** with the varying thickness without limiting the scope of the disclosure.

Referring to FIG. **2**A, a reinforcing insert **202** is provided, at least partly, within the first end **104** of the tube **102**. In the illustrated embodiment, the reinforcing insert **202** has a substantially planar shape. Accordingly, the reinforcing insert **202** may include a metal strip, a portion of sheet metal, and the like. In other embodiments, as shown in FIG. **2**B, the reinforcing insert **204** may have a substantially cylindrical shape. In the illustrated embodiment, the reinforcing insert **204** has a substantially hollow, tubular shape. In other embodiments, the reinforcing insert **204** may have a substantially solid, rod like shape. The reinforcing insert **202**, **204** may be made of a reinforcing material, such as a metal, an alloy, and the like. The method of manufacturing the damper tube **502** will be further explained with reference to the reinforcing insert **202** having the planar shape for the purpose of clarity and explanation. It should be noted that, in other embodiments, the damper tube **502** may be manufactured using the reinforcing insert **204** having the cylindrical shape without limiting the scope of the disclosure.

Referring to FIGS. **3**A and **3**B, the first end **110** of the tube **108** having the reinforcing insert **202** is flattened. More specifically, as shown in FIG. **3**A, the first end **110** of the tube **108** along with the reinforcing insert **202** is placed between a flattening die **302** and a flattening press **304**. The flattening die **302** and the flattening press **304** may be configured based on the thickness and a diameter of the tube **108** and/or of the reinforcing insert **202**. Further, as shown in FIG. **3**B, the flattening press **304** may exert pressure on the first end **110** of the tube **108** to flatten a portion **306** of the first end **110** of the tube **108**, such that the tube **108** contacts the reinforcing insert **202**. As such, the reinforcing insert **202** is sandwiched between the flattened portion **306** of the first end **110** of the tube **108**.

In the illustrated embodiment, the first end **110** of the tube **108** is flattened in a manner, such that the flattened portion **306** is disposed at an offset "F" with respect to the central axis X-X' of the tube **108**. In other embodiments, as shown in FIG. **3**C, the first end **110** of the tube **108** may be flattened in a manner, such that the flattened portion **306** is aligned with respect to the central axis X-X' of the tube **108**. In some embodiments, when the reinforcing insert **204** may have the cylindrical shape as described in FIG. **2**B, the reinforcing insert **204** may be flattened along with the first end **110** of the tube **108**.

More specifically, as shown in FIG. **3**D, the first end **110** of the tube **108** along with the reinforcing insert **204** is placed between the flattening die **302** and the flattening press **304**. Further, as shown in FIG. **3**E, the flattening press **304** may exert pressure on the first end **110** of the tube **108** to flatten the portion **306** of the first end **110** of the tube **108** along with the reinforcing insert **204**. As such, the reinforcing insert **204** is flattened and sandwiched between the flattened portion **306** of the first end **110** of the tube **108**.

It should be noted that, in some embodiments, an additional trimming process (not shown) may be employed using a dedicated set of dies and/or tools (not shown) in order to trim and/or shape one or more end corners and/or an end boundary of the flattened portion **306** of the tube **108**. In such a situation, the trimmed portion of the flattened portion **306** of the tube **108** may be welded to provide sealing and corrosion resistance to the flattened portion **306** of the tube **108**. In some embodiments, a thickness of the flattened portion **306** of the tube **108** may be increased prior to flattening using known manufacturing processes. Also, it should be noted that, in some embodiments, as shown in FIGS. **8**A to **8**D, the portion **306** of the first end **110** of the tube **108** may be partially flattened without the reinforcing insert **202**, such that the reinforcing insert **202** may be inserted later in the partially flattened portion **306**. The manufacturing process will be explained later in more detail with reference to FIGS. **8**A and **8**D.

Referring to FIGS. **4**A to **4**C, the reinforcing insert **202** and the flattened portion **306** of the tube **108** are bent into a loop **402**. More specifically, as shown in FIGS. **4**A and **4**B, a first tool **404** and a first die **406** are provided in contact with the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**. The first tool **404** and the first die **406** are adapted to partly bend the reinforcing insert **202** and the flattened portion **306** of the tube **108**. The first tool **404** may be a punch tool, such as a gooseneck punch or any other tool adapted to bend the reinforcing insert **202** and the flattened portion **306** of the tube **108**. It should be noted that, in some embodiments, the first tool **404** and the first die **406** shown in each of the FIGS. **4**A and **4**B may include varying configurations in order to enable progressive bending of the reinforcing insert **202** and the flattened portion **306** of the tube **108**.

Further, as shown in FIG. **4**C, the first tool **404** and the first die **406** are replaced with a second tool **408**, a curling press **410**, and a curling die **412**. More specifically, the second tool **408**, the curling press **410**, and the curling die **412** are provided in contact with the partly bent reinforcing insert **202** and the flattened portion **306** of the tube **108** of FIG. **4**B. The second tool **408**, the curling press **410**, and the curling die **412** are adapted to bend the partly bent reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** into the loop **402**.

The second tool **408** may be a curling tool or any other tool adapted to provide support to the flattened portion **306** of the tube **108** during curling of the reinforcing insert **202** and the flattened portion **306** of the tube **108** into the loop **402**. In some embodiments, the second tool **408** may be a bushing (not shown) used in the shock absorber. The bushing may provide a stiff connection between a vehicle chassis and the shock absorber. In a situation when the bushing may include an outer sleeve (not shown), such as a metallic rim, the bushing may provide reinforcement and support to the flattened portion **306** of the tube **108** during the curling process.

Further, the second tool **408** may be removed from the loop **402** to complete the bending process. It should be noted that the tools, the presses, the dies, and the bending process, described herein with reference to FIGS. **4**A to **4**C are merely exemplary and may vary based on application requirements. For example, in some embodiments, the bending process may be completed in a single step by using a single set of a tool and a die. In other embodiments, the bending process may be completed in multiple steps by using multiple sets of tools and dies, such as by forming multiple small bends adjacent to one another in the flattened portion **306** of the tube **108** by pushing the flattened portion **306** of the tube **108** against the first tool **404** or vice versa. Also, it should be noted that, although the bending and curling process is described herein with reference to the reinforcing insert **202**, the reinforcing insert **204** and the flattened portion **306** of the tube **108** may be bent and curled into the loop **402** in a manner similar to that described with reference to FIGS. **4**A to **4**C.

It should be noted that, in the illustrated embodiment, each of the flattening die **302**, the flattening press **304**, the first die **406**, the curling press **410**, and the curling die **412** is exemplarily shown in a substantially vertical orientation. In other embodiments, one or more of the flattening die **302**, the flattening press **304**, the first die **406**, the curling press **410**, and the curling die **412** may be oriented in any other manner, such as inclined or horizontally. Also, the flattening die **302** and the flattening press **304** may be configured in a manner to perform on-center or off-center flattening of the portion **306** of the tube **108** with respect to the central axis X-X', based on application requirements.

In some embodiments, the reinforcing insert **202** and the flattened portion **306** of the tube **108** may be heated prior to or during the bending process. The heating of the reinforcing insert **202** and the flattened portion **306** of the tube **108** may limit material failure due to straining and/or plastic deformation and may improve formability. Also, the heating of the reinforcing insert **202** and the flattened portion **306** of the tube **108** when employed in combination with the second tool **408** during the bending process may limit spring back effect in the loop **402**. The heat may be applied using a heating method, such as a gas torch heating, laser assisted heating and bending, induction heating, furnace heating, infrared lamp heating, and the like.

In some embodiments, the spring back effect in the loop **402** may be limited by using spring back compensation techniques, such as forming, measuring, and compensation. In some embodiments, the spring back effect in the loop **402** may be limited by using laser assisted in-process measuring of a bending angle in order to allow in-process monitoring and correction of the bending angle. Also, the reinforcing insert **202** improves strength and stiffness of the loop **402** under dynamic and/or static loading conditions. In some embodiments, the variable thickness of the tube **102** (as shown in FIG. **1**B) along with the reinforcing insert **202** may add structural rigidity to the loop **402**.

Referring to FIGS. **5**A, **5**B, **5**C, **5**D and **5**E, an edge **504** of the loop **402** is connected to the tube **108**. More specifically, the edge **504** of the loop **402** is connected to the tube **108** by a weld **506** in order to seal the edge **504**, limit straightening of the loop **402**, and/or provide structural rigidity to the loop **402**. It should be noted that a length of the flattened portion **306** and/or a length of the reinforcing insert **202** may be approximately equal to a circumference of the loop **402**. In some embodiments, as shown in FIG. **5**A, a center "C" of the loop **402** may be aligned with respect to the central axis X-X' of the damper tube **502**. In some embodiments, as shown in FIG. **5**B, the center "C" of the loop **402** may be disposed at an offset "F" with respect to the central axis X-X' of the damper tube **502**. Such a configuration of the loop **402** with respect to the central axis X-X' may provide increased stiffness and load bearing capacity of the loop **402** and/or the damper tube **502**.

Referring to FIG. **5**C, an embodiment of the damper tube **508** formed with the tube **102** having the varying thickness (as shown in FIG. **1**A) is illustrated. The damper tube **508** includes a configuration and method of manufacturing substantially similar to that of the damper tube **502**. It should be noted that, in the illustrated embodiment, a substantial portion of the tube **102** having the first thickness "T**1**" is bent into the loop **402**. In other embodiments, a portion of the tube **102** bent into the loop **402** may vary based on application requirements.

Referring to FIG. **5**D, in some embodiments, each of the flattened portion **306** of the tube **108** and the center "C" of the loop **402** may be aligned with respect to the central axis X-X' of the damper tube **502**. Referring to FIG. **5**E, in some embodiments, the insert **202** may include a length substantially shorter than the circumference of the loop **402**. In such a situation, the insert **202** may be provided in a region of maximum stress concentration. Further, the insert **202** may not be bent. Further, in some embodiments, inner surfaces **510**, **512** of the loop **402** beyond the insert **202** may contact each other, as shown. Additionally, in some embodiments, the weld **506** may couple both the edge **504** and the insert **202** with the loop **402**. In some embodiments, one or more notches **514** may be provided on the inner surface **516** of the damper tube **108**. The notch **514** may be adapted to support a base valve (not shown) of the shock absorber.

Referring to FIG. **6**, a flowchart of a method **600** of manufacturing the damper tube **502** is illustrated. At step **602**, the tube **108** having the first end **110** and the second end **112** opposite to the first end **110** is provided, as described with reference to FIG. **1**B. In some embodiments, as described with reference to FIG. **1**A, the tube **102** may include a first thickness "T1" of the first end **104** of the tube **102** different from the second thickness "T2" of the second end **106** of the tube **102**. At step **604**, the reinforcing insert **202** is provided, at least partly, within the first end **110** of the tube **108**, as described with reference to FIGS. **2**A and **2**B. In some embodiments, as described with reference to FIG. **2**A, the reinforcing insert **202** has the substantially planar shape such that the first end **110** of the tube **108** is flattened to contact the reinforcing insert **202**. In some embodiments, as described with reference to FIG. **2**B, the reinforcing insert **204** has the substantially cylindrical shape such that the reinforcing insert **204** is flattened along with the first end **110** of the tube **108**. At step **606**, the portion of the first end **110** of the tube **108** is flattened, as described with reference to FIGS. **3**A to **3**E.

At step **608**, at least one of the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** is bent into the loop **402**, as described with reference to FIGS. **4**A to **4**C. More specifically, the first tool **404** is provided in contact with the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**. The first tool **404** is adapted to at least partly bend the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**. Further, the first tool **404** is replaced with the second tool **408** in contact with the partly bent reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**. The second tool **408** is adapted to bend the partly bent reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** into the loop **402**.

Further, the second tool **408** is removed from the loop **402** to complete the curling process. In some embodiments, the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** may be heated during the bending and/or curling process. At step **610**, the edge **504** of the loop **402** is connected to the tube **108** by the weld **506**, as described with reference to FIGS. **5**A, **5**B, **5**C, **5**D and **5**E. In some embodiments, the center "C" of the loop **402** is aligned with respect to the central axis X-X' of the tube **108**, as described with reference to FIGS. **5**A, **5**C, **5**D and **5**E. In some embodiments, the center "C" of the loop **402** is disposed at the offset "F" with respect to the central axis X-X' of the tube **108**, as described with reference to FIG. **5**B.

Referring to FIG. **7**, an alternate method **700** of manufacturing the damper tube **502** is illustrated. The method **700** will now be explained with combined reference to FIGS. **1** to **8**. At step **702**, the tube **108** is provided having the first end **110** and the second end **112** opposite to the first end **110**, as described with reference to FIGS. 1A and 1B. At step **704**, and referring to FIG. **8**A, a mandrel or a spacer tool **802** is provided, at least partly, within the first end **110** of the tube **108**. The spacer tool **802** may be inserted from the first end **110** or the second end **112** of the tube **108**. In the illustrated embodiment, the spacer tool **802** has a substantially planar shape. In other embodiments, the spacer tool **802** may have a substantially cylindrical shape. Also, in some embodiments, a width of the spacer tool **802** may be equal to an inner diameter of the tube **108** prior to flattening of the tube **108**. Accordingly, the spacer tool **802** may include a metal strip, a portion of sheet metal, and the like. At step **706**, and referring to FIG. **8**B, the portion of the first end **110** of the tube **108** is flattened, as described with reference to FIGS. **3**A to **3**E, such that the tube **108** contacts the spacer tool **802**.

At step **708**, and referring to FIG. **8**C, the spacer tool **802** is removed from the flattened portion **306** of the first end **110** of the tube **108**. At step **710**, and referring to FIG. **8**D, the reinforcing insert **202** is provided within the flattened portion **306** of the first end **110** of the tube **108**. The reinforcing insert **202** has the substantially planar shape, as described with reference to FIG. **2**A, such that the first end **110** of the tube **108** is flattened to contact the reinforcing insert **202**. In some embodiments, the flattened portion **306** of the first end **110** of the tube **108** may be re-flattened, such that the tube **108** contacts the reinforcing insert **202** and any clearance between the reinforcing insert **202** and the flattened portion **306** of the tube **108** is removed.

At step **712**, at least one of the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** are bent into the loop **402**, as described with reference to FIGS. **4**A to **4**C. More specifically, the first tool **404** is provided in contact with the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**. The first tool **404** is adapted to at least partly bend the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**. Further, the first tool **404** is replaced with the second tool **408** in contact with the partly bent reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108**.

The second tool **408** is adapted to bend the partly bent reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** into the loop **402**. Further, the second tool **408** is removed from the loop **402** to complete the curling process. In some embodiments, the reinforcing insert **202** and the flattened portion **306** of the first end **110** of the tube **108** may be heated during the bending and/or curling process. At step **714**, the edge **504** of the loop **402** is connected to the tube **108** by the weld **506**, as described with reference to FIGS. **5**A, **5**B, **5**C, **5**D and **5**E.

In some embodiments, one or more tools, dies, presses, and/or machines (not shown) having similar or dissimilar working capacities may be employed in a synchronized operational configuration in order to improve productivity. The synchronized operation of the machines may be controlled via Computer Numeric Control (CNC). Additionally, or optionally, an integrated automated tool changing system (not shown) having a library of various tooling may be used in tool changing operation. In some embodiments, different machines may be operated independently in order to improve flexibility of the process. In some embodiments, the complete process may be automated, such that multiple tubes may be processed using a single operation. Moreover, completion of multiple tasks such as tube end reduction/expansion, flattening (with or without trimming), and curling may be achieved using, for example, custom work benches having combined hydraulic units.

In such situations, a controller (not shown) may be employed in order to automate the process. The controller may be communicably coupled to the one or more machines. The controller may be a control unit configured to perform various functions of the process. In one embodiment, the controller may be a dedicated control unit configured to perform functions related to the process. In another embodiment, the controller may be a Machine Control Unit (MCU) associated with the one or more machines to perform functions related to the process.

The method **600**, **700** provides a simple and effective process to flatten, bend, and curl the damper tube **502**, **508** by limiting operational steps, process components, and multiple joints or welds. The limitation of the joint to the single weld **506** may improve corrosion resistance and durability of the damper tube **502**, **508**. Also, in situations when the tube **102** with variable thickness may be used, an overall weight of the damper tube **508** may be substantially reduced while providing reinforcement at the loop **402**. As such, the method **600**, **700** provides a simplified structure of the damper tube **502**, **508** in order to reduce manufacturing and/or assembly complexity and costs.

While aspects of the present disclosure have been particularly shown and described with reference to the embodiments above, it will be understood by those skilled in the art that various additional embodiments may be contemplated by the modification of the disclosed machines, systems and methods without departing from the spirit and scope of what is disclosed. Such embodiments should be understood to fall within the scope of the present disclosure as determined based upon the claims and any equivalents thereof.

What is claimed is:

1. A method of manufacturing a damper tube, the method comprising:
- providing a tube having a first end and a second end opposite to the first end;
- providing a spacer tool, at least partly, within the first end of the tube;
- flattening a portion of the first end of the tube such that the tube contacts the spacer tool;
- removing the spacer tool from the flattened portion of the first end of the tube;
- providing a reinforcing insert within the flattened portion of the first end of the tube;
- bending at least one of the reinforcing insert and the flattened portion of the first end of the tube into a loop; and
- connecting an edge of the loop to an outer side surface of the tube.

2. The method of claim **1**, wherein bending the at least one of the reinforcing insert and the flattened portion further includes providing a first tool in contact with the at least one of the reinforcing insert and the flattened portion of the first end of the tube, the first tool adapted to at least partly bend the at least one of the reinforcing insert and the flattened portion of the first end of the tube.

3. The method of claim **2**, wherein bending the at least one of the reinforcing insert and the flattened portion further includes replacing the first tool with a second tool in contact with the partly bent at least one of the reinforcing insert and the flattened portion of the first end of the tube, the second tool adapted to bend the partly bent at least one of the reinforcing insert and the flattened portion of the first end of the tube into the loop.

4. The method of claim **3**, wherein bending the at least one of the reinforcing insert and the flattened portion further includes removing the second tool from the loop.

5. The method of claim **1**, wherein bending the at least one of the reinforcing insert and the flattened portion further includes heating the at least one of the reinforcing insert and the flattened portion of the first end of the tube.

6. The method of claim **1**, wherein providing the reinforcing insert within the flattened portion further includes re-flattening the flattened portion of the first end of the tube such that the tube contacts the reinforcing insert.

7. The method of claim **1**, wherein the edge of the loop is connected to the outer side surface of the tube by welding.

8. The method of claim **1**, wherein the spacer tool has a planar shape disposed within the first end of the tube.

9. The method of claim **1**, wherein the reinforcing insert has a planar shape disposed within the first end of the tube.

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